World Without Waste: *Energy Rebound*

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AGENDA

- **Basic Idea of Energy Rebound**
- **Key Quantities**
- **Our Understanding of Rebound Magnitudes**
- **Rebound and Stage of Economic Development**
- **Link to Resource/Waste Rebound Generally**
- **Literature and Expert Contacts**

Basic Idea of "energy efficiency" Rebound

Simplest concept:

- When a new technology enables more energy services to be provided per unit of physical energy, it looks to the user like a price reduction.
- A price reduction typically causes a demand increase
  - Energy services demand goes up, and the physical energy to supply it follows.
  - This is offset by a reduction in physical energy use owing to the efficiency gain.
  - The resulting physical energy use depends on the balance, but will be higher than projected assuming only the % efficiency gain portion.

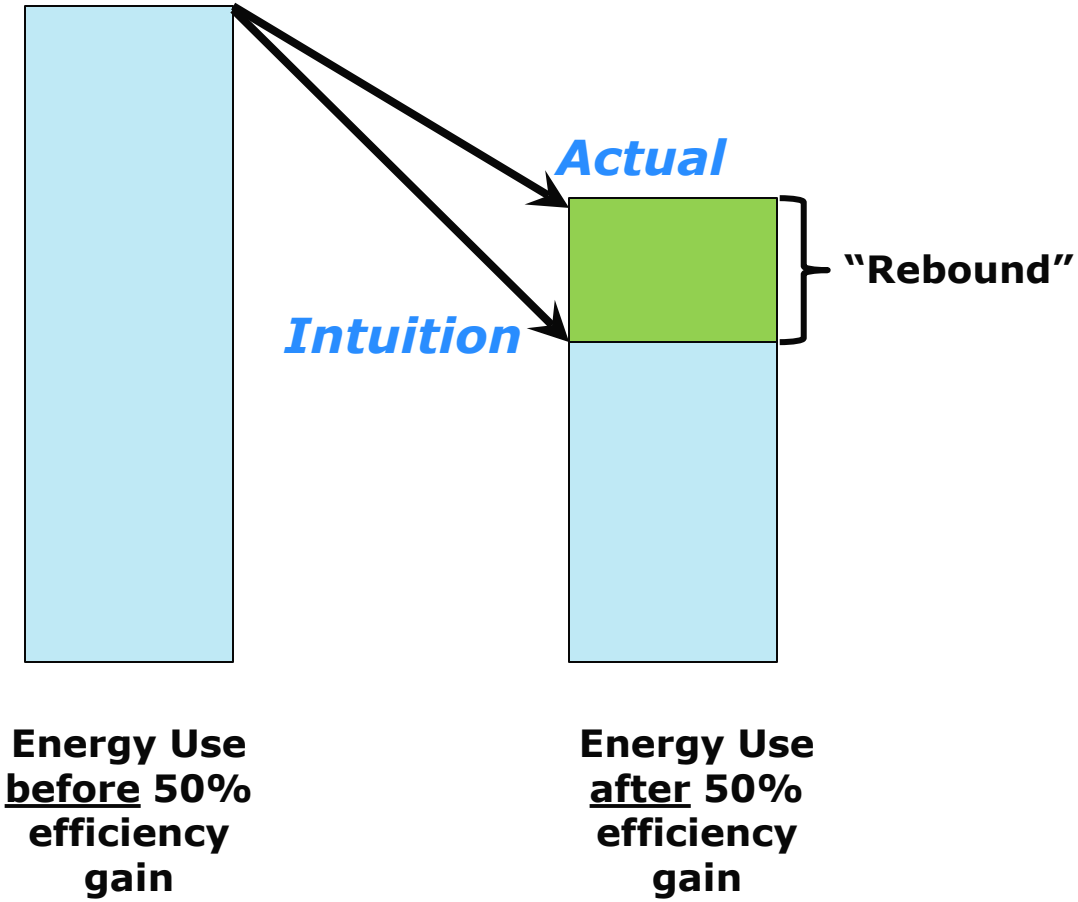
Basic Idea of "energy efficiency" Rebound (continued)

"A price reduction typically causes a demand increase":

- How much? You ask.
- It depends primarily on two things:
  - The extent to which the physical (productive) economy is flexible enough to take advantage of the cheaper energy services to substitute for other inputs to production (capital, labor). *Embodied formally in the "elasticities of factor substitution."*
  - The extent to which households substitute, as a result of cheaper energy services, in a way so as to alter their consumption baskets toward more energy-intensive goods and services. *Embodied formally in the "price elasticities."*

Energy efficiency gains do not operate as intuition might suggest.

Consider a new technology whose engineering efficiency gain is 50% (i.e. produces the same energy services with half the physical energy input):



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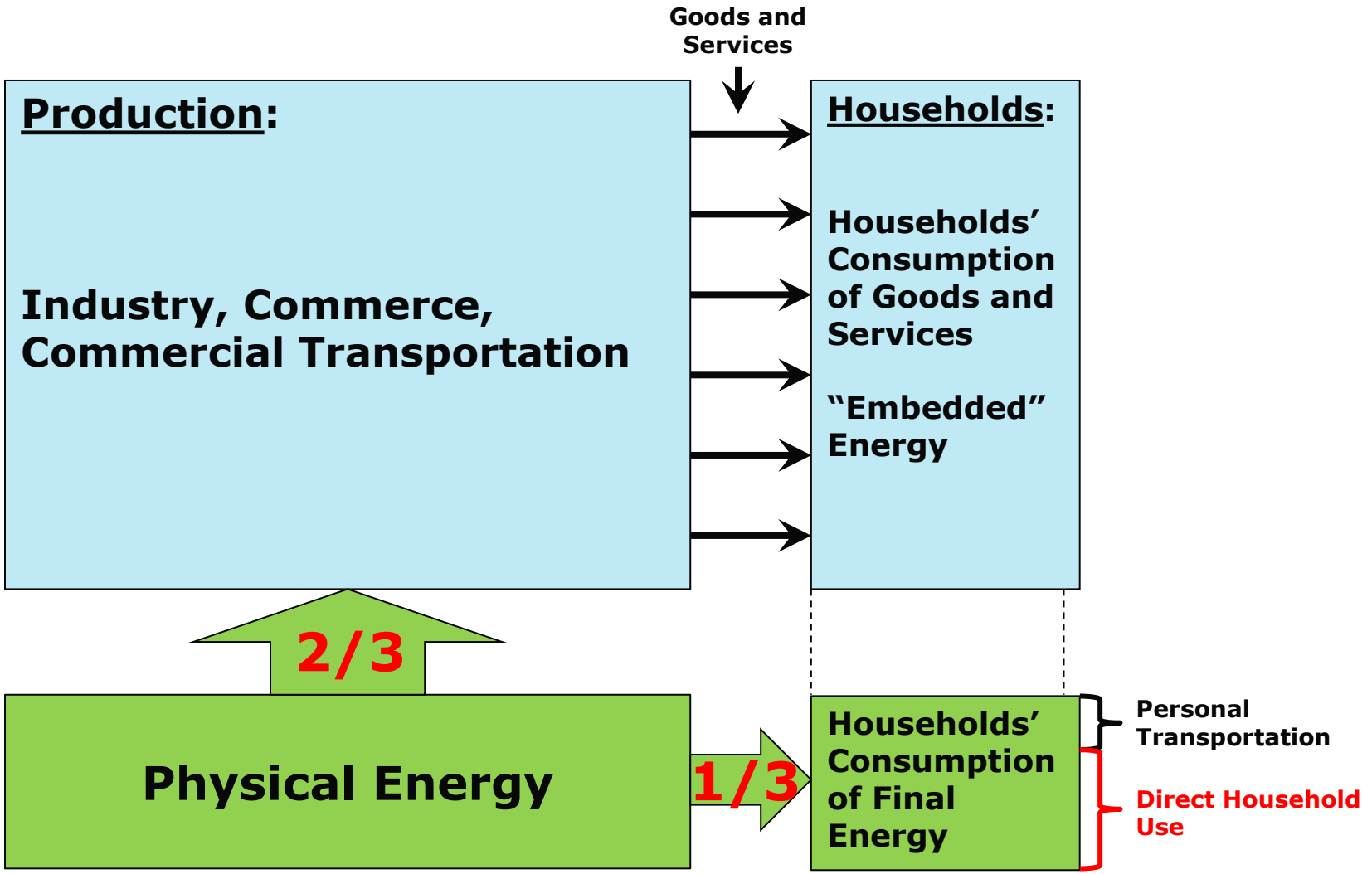
Distribution of Energy Use



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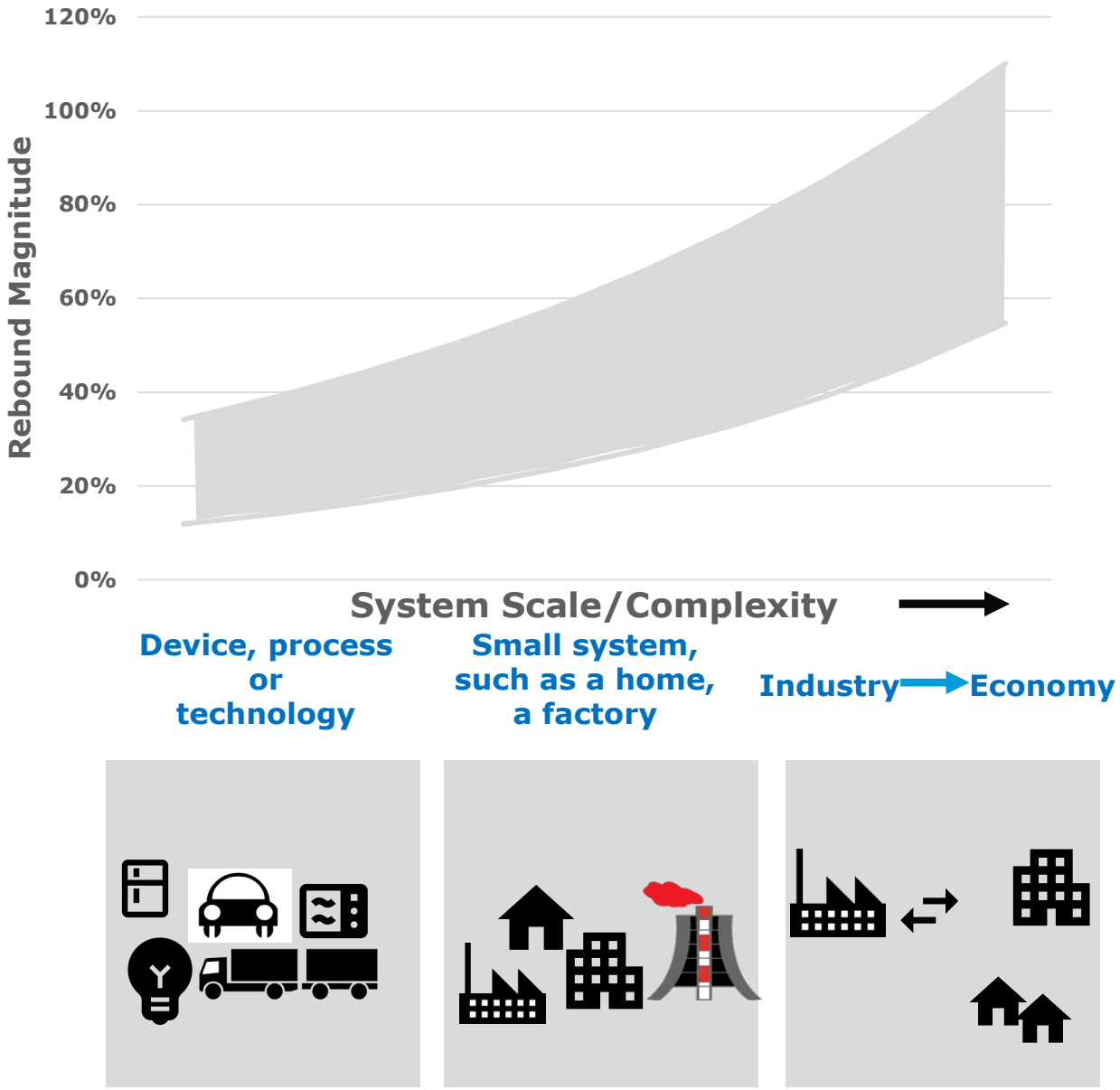
Rebound magnitudes are uncertain, but increase with system scale and complexity



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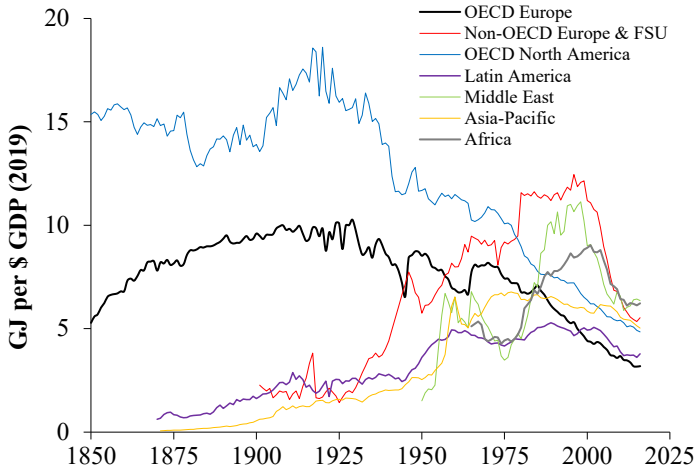
Energy Intensity

"Energy Intensity" is a crude, imperfect, but useful proxy for tracking energy efficiency

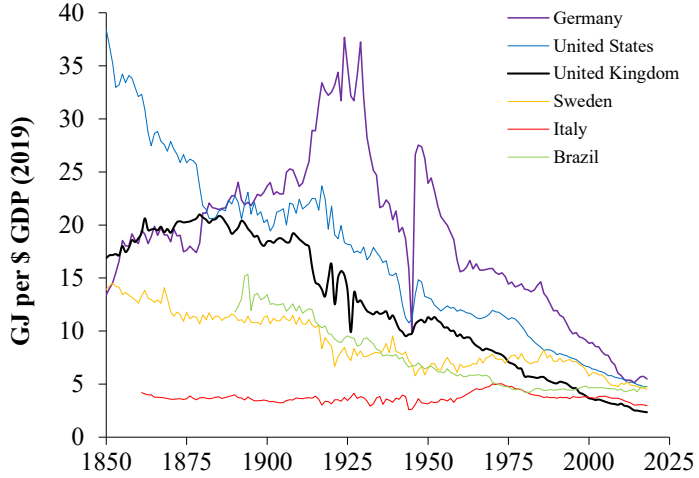
- Energy Intensity I = E/Y
  - where E is physical energy use and Y is useful output, often GDP
- The rate of decline of energy intensity is often treated as the rate of energy efficiency improvement
- However, many things besides energy efficiency affect both the numerator and denominator of energy intensity.
- When used as a metric of energy efficiency gain, forecasts of intensity have been well off the mark (e.g., IEA). Probably because they ignore rebound effects.

Energy Intensity is larger in earlier stages of development

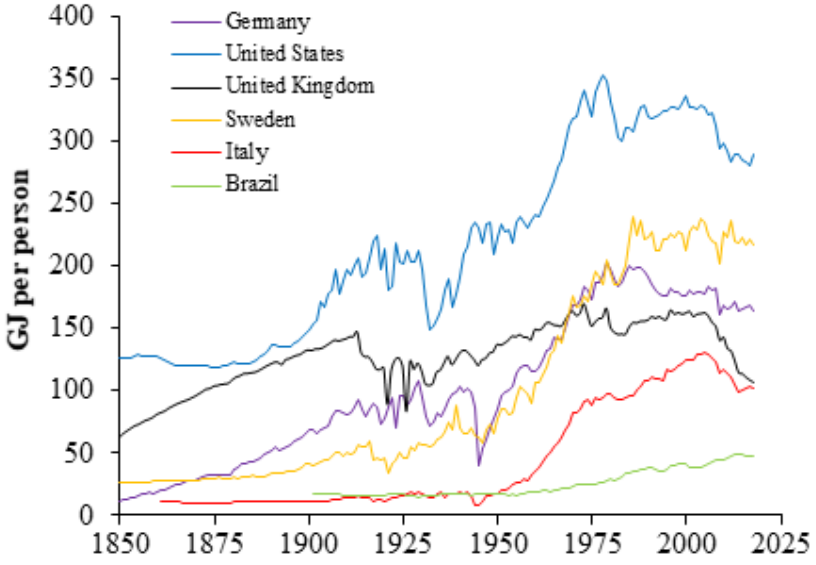
(a)



Energy Intensity (b)



(c)



Energy per Capita

There are ethical tradeoffs with respect to rebound

…arising in discussions about policy measures to suppress rebound

- Rebound means energy efficiency gains do not reduce physical energy use – and associated emissions – as much as might be hoped for
- HOWEVER, rebound *increases* economic welfare
- Countries in the early stages of development need more physical energy per unit output, as they build out the infrastructure of modernity.
- "Rebound suppressing" policies come at the cost of reduced welfare, especially for those in energy poverty
- Developing countries will likely make the tradeoff in favor of increased welfare rather than reduced energy use.

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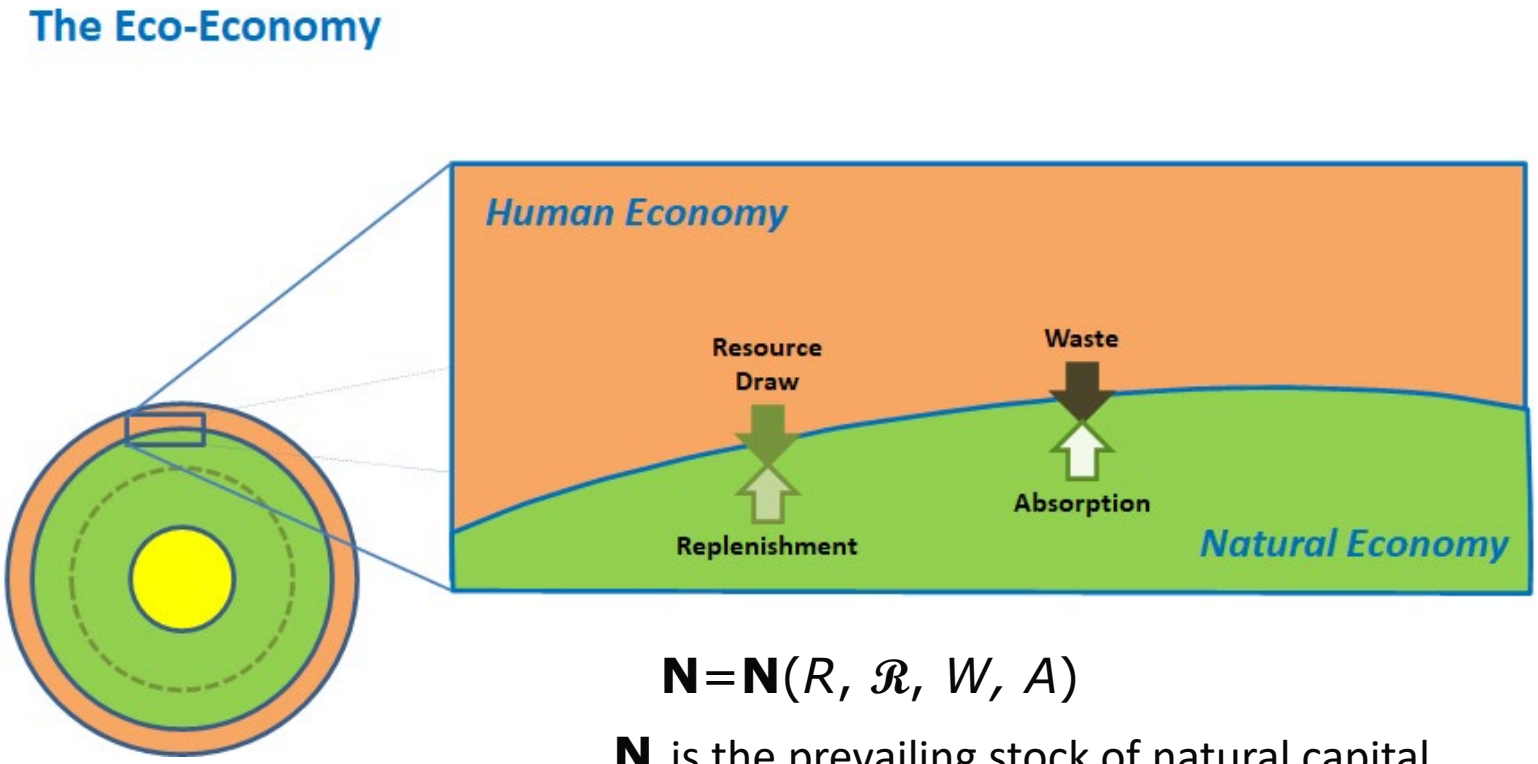
The Eco-economy, simplified



$\mathbf{N} = \mathbf{N}(R, \mathcal{R}, W, A)$

N is the prevailing stock of natural capital

R is the current natural ***resource*** *draw*

$\mathcal{R}$ *is Replenishment of natural capital*

W is the **waste inflicted** on natural capital

A is the **waste absorbed** by natural capital

From this comes a simple (simplistic!) equation

$$\mathbf{N_t = N_{t-1}} + (\mathcal{R}_t - R_t) + (A_t - W_t)$$

- When *R* (resource use) is substituted to replace E (energy) in a neoclassical model, *R* experiences rebound
  - So there is *general* resource rebound
- There are early indications that waste *W* likewise exhibits rebound behavior
  - When waste reduction/disposal efficiency increases, the quantity of waste inflicted on natural capital is greater than intuition would suggest.

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Waste Rebound Experts

	Davis/Burgess/Hegwood Team		
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General Reference: Waste Rebound

Trevor Zink, Roland Geyer, "Circular Economy Rebound," *Journal of Industrial Ecology*, 21(3) 2017
https://doi.org/10.1111/jiec.12545

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Key Reference	**D. Fullerton and C. Ta**, "Costs of Energy Efficiency Mandates can Reverse the Sign of Rebound," 2020.*Journal of Public Economics*, 188, [104225]. https://doi.org/10.1016/j.jpubeco.2020.104225	**D. I. Stern**, "How large is the economy-wide rebound effect?," *Energy Policy,* vol. 147, no. August, p. 111870, 2020, doi: 10.1016/j.enpol.2020.111870.	**Lemoine D**, "General Equilibrium Rebound from Energy Efficiency Innovation," Working Paper 25172, 2018. [Online]. Available: http://www.nber.org/papers/w25172.	**A. L. Hicks and T. L. Theis**, "An agent based approach to the potential for rebound resulting from evolution of residential lighting technologies," *Int. J. Life Cycle Assess*., vol. 19, no. 2, pp. 370–376, 2014, doi: 10.1007/s11367-013-0643-8.	

General Reference: Energy Rebound
(Rebound section lists multiple references)

"Energy Efficiency: what has research delivered in the last 40 years?"

Annual Review of Environment and Resources , 2021 (accepted, in press)

Link to Working Paper: https://www.fcn.eonerc.rwth-aachen.de/cms/E-ON-ERC-FCN/Forschung/~emvl/Arbeitspapiere/lidx/1/

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QUESTIONS/COMMENTS/ DISCUSSION

BACKUP SLIDES

Overall Structure